

Vannevar Bush's Differential Analyzer

Mechanical differential analyzers have been praised for their educational value. In his autobiography [1] Vannevar Bush tells the story of a draftsman who learned differential equations in mechanical terms from working on the construction and maintenance of the MIT differential analyzer. After the last differential analyzer at MIT was decommissioned, Warren Weaver wrote to Samuel Caldwell:

[I]t seems rather a pity not to have around such a place as MIT a really impressive Analogue computer; for there is vividness and directness of meaning of the electrical and mechanical processes involved... which can hardly fail, I would think, to have a very considerable educational value. A Digital Electronic computer is bound to be a somewhat abstract affair, in which the actual computational processes are fairly deeply submerged. [2]

In the place of an expensive reconstruction of the original high-precision machinery [3], we have completed a virtual reconstruction of the Bush Differential Analyzer. Based on original descriptions and photographs of the computer [4], a graphical model of the computer has been constructed using Maya Complete 6.0, a 3-D modeling software package.

Video and Images

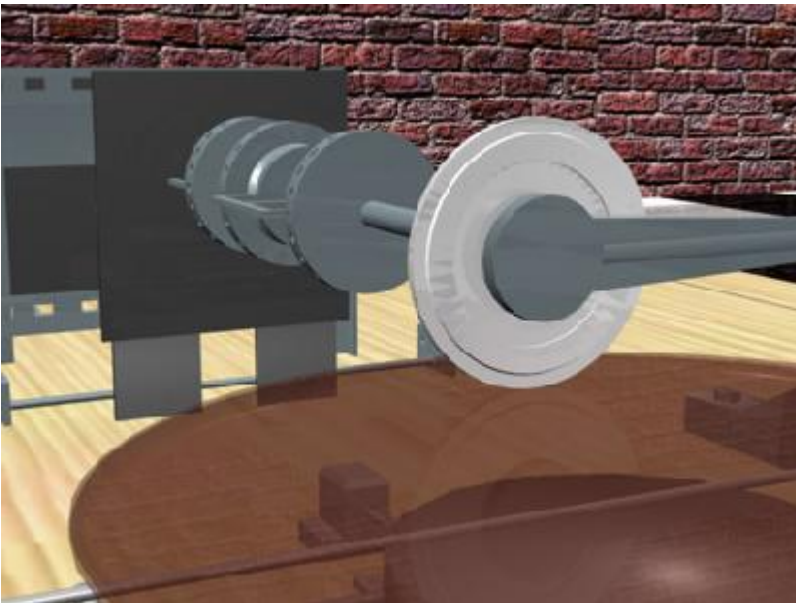
Three-dimensional modeling by Vitaliy Pereverzev, under the supervision of Dr. Kent Lundberg [5].

The analyzer is modeled with a physical description of spline curves and meshes of polygons. The scene is illuminated with three sources of light, one directional source and two ambient sources, to enhance the appearance of the components. Texture maps of metal, wood, brick, and floor tiles are used to add detail to the rendered objects.

The complete model is animated to show the operation of the machine solving differential equations. Several days of computer time are needed to produce the individual frames for a single animation. The final video is assembled using Adobe AfterEffects and compressed using the DivX codec.

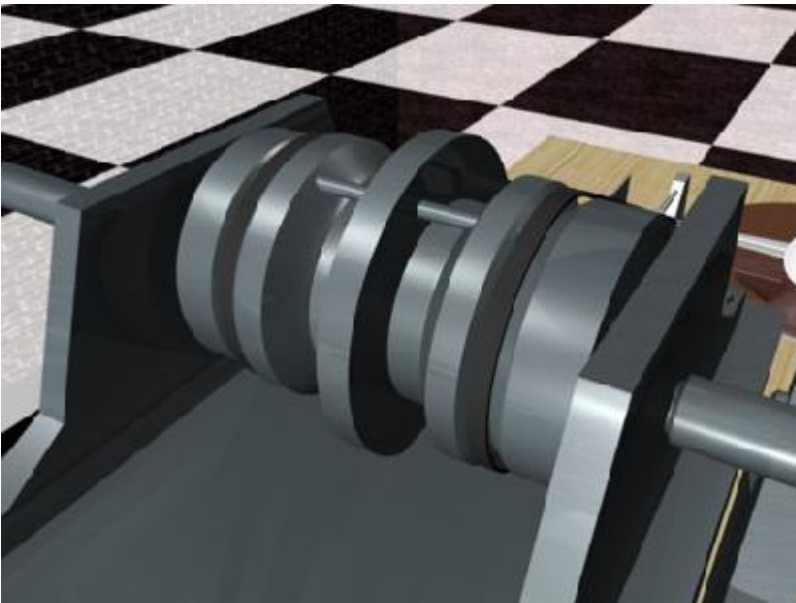
- [Animated video \(31M\)](#) of the machine solving a second-order differential equation (4 June 2005). Requires Quicktime.
- [Animated video \(12.8M\)](#) of the machine with moving parts (28 Oct 2004). Requires the [DivX codec](#).
- [Some early sketches of the parts](#)

Wheel-and-disk integrator



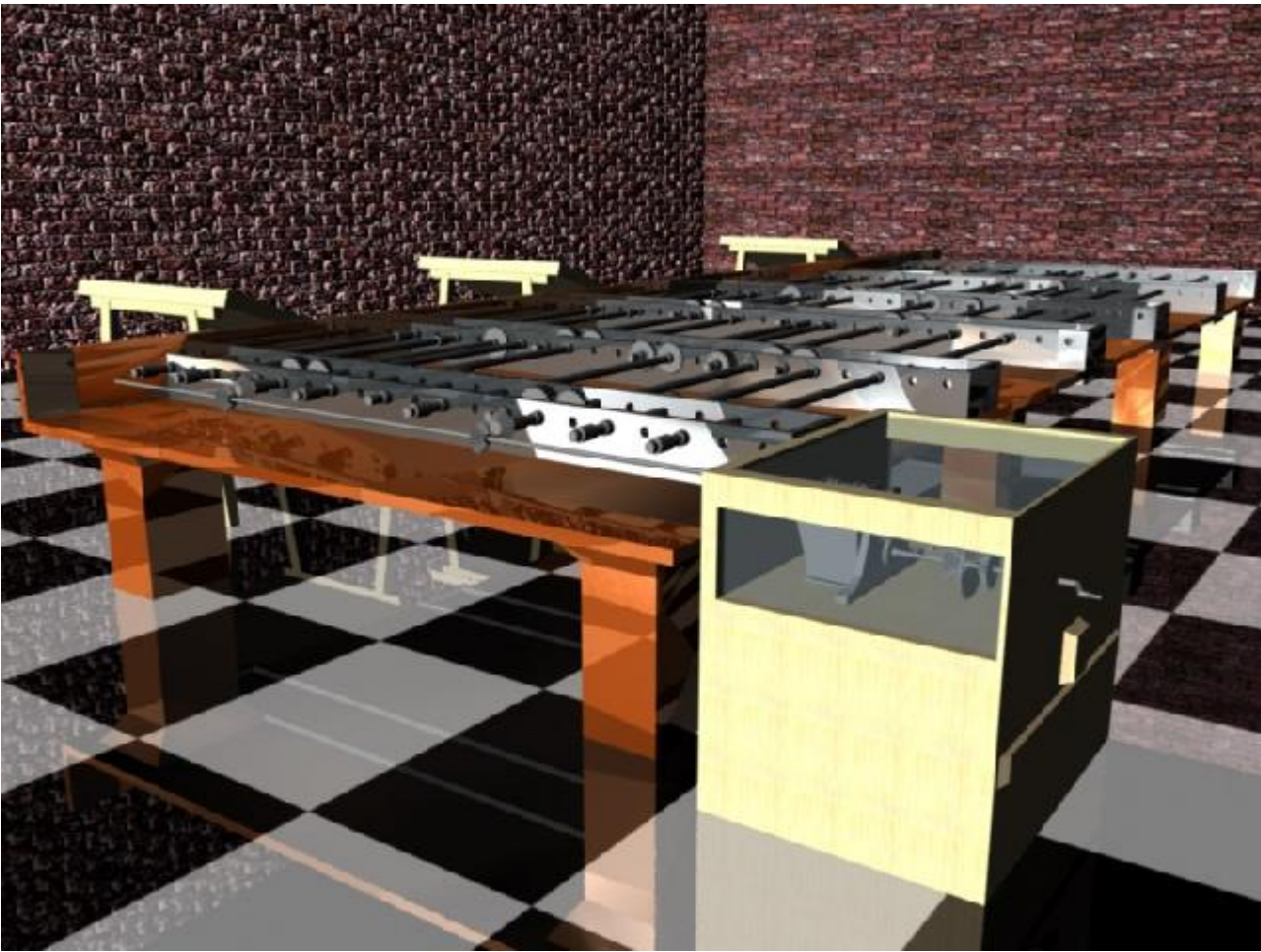
(LEFT) Original wheel-and-disc integrator from Bush's differential analyzer on display at the MIT Museum. This view shows the glass disc and the metal wheel that implemented integration in the computer. (RIGHT) Animated wheel-and-disc integrator. The animated integrator demonstrates the operation of this clever mechanism, providing insight into the operation of the differential analyzer.

Torque amplifier



(LEFT) Original Nieman torque amplifier on display at the MIT Museum. This torque amplifier, based on contra-rotating capstans, amplifies the output from the integrator wheel and drives the output gears of the integrator box. (RIGHT) Animated torque amplifier. By watching a short animation of the torque amplifier in operation, students can observe and learn the principles behind the amplifier's operation.

Views of the whole machine



References

- [1] V. Bush, *Pieces of the Action*, New York, Morrow, 1970.
- [2] L. Owens, "Vannevar Bush and the differential analyzer: the text and context of an early computer," *Technology and Culture*, vol. 27, no. 1, pp. 63--95, Jan. 1986.
- [3] D.A. Mindell, ["MIT Differential Analyzer,"](#) [Online].
- [4] V. Bush and H. Hazen, "The differential analyzer: a new machine for solving differential equations," *Journal of the Franklin Institute*, vol. 212, no. 4, pp. 447--488, Oct. 1931.
- [5] K. Lundberg and V. Pereverzev, "Virtual differential analyzer reconstruction," *IEEE Control Systems Magazine*, vol. 25, no. 3, June 2005.

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